Availability and Performance Evaluation of your PDH/SDH Networks

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In many situations, the evaluation of the quality of a transmission line is more than a simple need in terms of bringing into service, acceptance, commissioning after repair, or assessing whether objectives have been reached.

A proper evaluation of quality will bring confidence in the network and will make the contractual relationship between customer and supplier far easier.

Quality has two different and complementary aspects: availability and performance.

For international links, ITU-T has defined a set of standards providing procedures, objectives and limits.For domestic links, each carrier can in theory define its own methodology. But, as some parts of the domestic network may become terrestrial extensions of an international path, it is widely accepted that these recommendations also apply to domestic transport networks.

The purpose of this technical paper is to answer the few questions any technician has when faced with availability or performance evaluations:

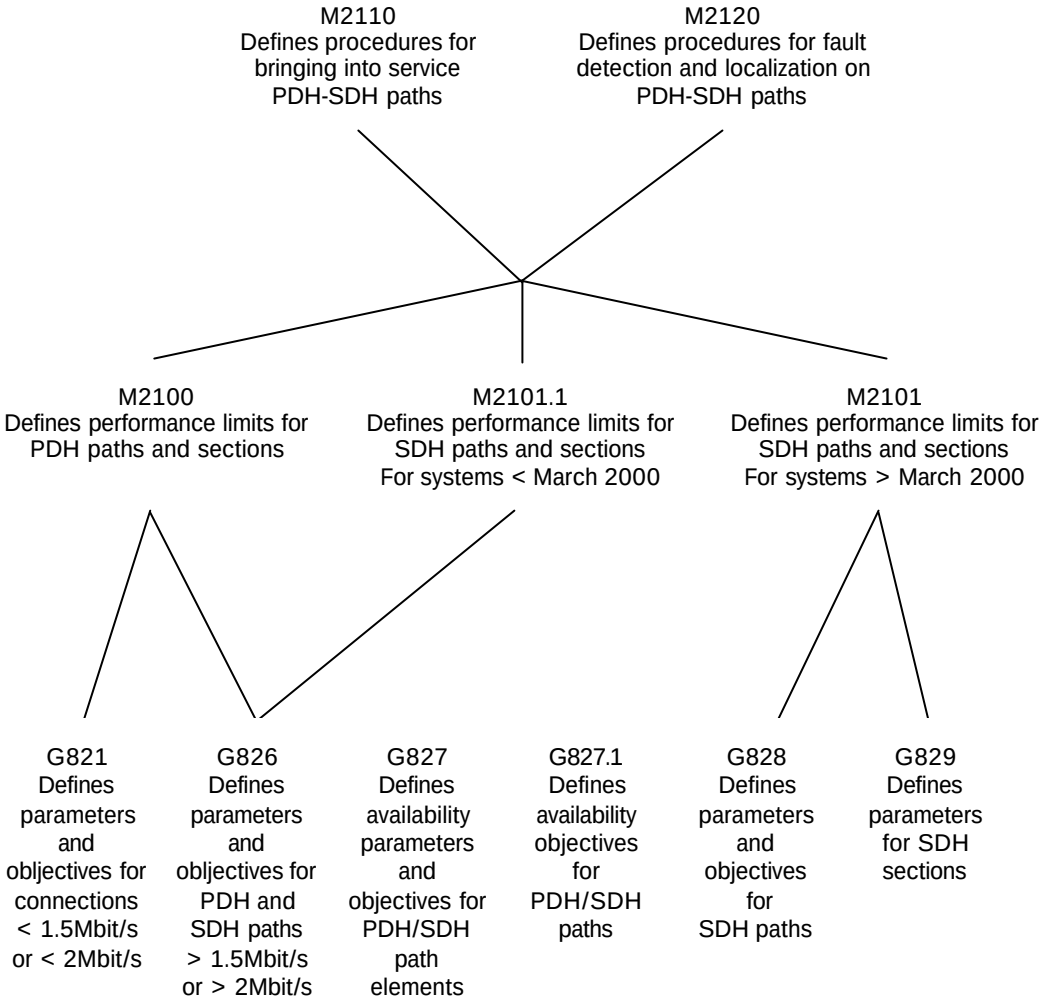
- **What standard should I use?**
- **What parameters should I monitor?**
- **What limit should I consider?**

First of all, we will summarize and clarify the relevant ITU-T standards. The purpose of the Trans'Expert, a NetTest Optical Transport Analyzer, is to provide trouble-free availability and performance evaluations.

Then, we will see how you can benefit from Trans'Expert's advanced performance evaluation functions for performing fast and accurate measurements, and then demonstrate your expertise to your customers.

1.0 the International Standards

Since the first G821 in the early 80s, ITU-T has defined a set of recommendations covering all aspects of performance evaluation from the basic event level up to the procedure level. The diagram below summarizes the structure of this set of recommendations.



The scope of each recommendation can also visualised as follows:

	Connections < 2Mbit/s	PDH > 2Mbit/s	SDH Paths < March 2000	SDH Paths > March 2000	SDH Sections
Procedures Fault Localization		M2120			
Installation		M2110			
Limits		M2100	M2101.1	M2101	M2101/M2101.1
Objectives Availability		G827/G827.1			
Performance		G826		G828	G829
Events and Parameters	G821				

2.0 The Block Concept

The conceptual definition of a block was introduced in G826 and remains valid in the current versions of G826, G828, G829 ITU recommandations: “a set of consecutive bits associated with the path or the section; each bit belongs to one and only one block; consecutive bits may not be contiguous in time”.

An error detection code (EDC) - BIP or CRC - is associated with each block. Each block is spread over a single frame but does not necessarily include all the bits of the frame. This is the major difference between G826/G828 and G829. The table given below summarizes the block characteristics for all paths and sections.

Path	Bite Rate Kbit/s	Bit/Block	Block/ Frame	Block/Sec	EDC	Byte
DS1	1544	4632	1	333	CRC-6	
E1	2048	2048	1/8	1000	CRC-4	
DS2	6312	3156	1	2000	CRC-5	
E2						
E3						
DS3	44736	4760	1	9398	BIP-1	
E4						
VC11	1644	832	1	2000	BIP-2	V5
VC12	2240	1120	1	2000	BIP-2	V5
VC2	6848	3424	1	2000	BIP-2	V5
VC3	48960	6120	1	8000	BOP-8	B3
VC4	150336	18792	1	8000	BIP-8	B3
VC4-4C	601344	75168	1	8000	BIP-8	B3
VC4-16C	2405376	300672	1	8000	BIP-8	B3
VC4-64C	9621504	1202688	1	8000	BIP-8	B3
STM0-MUX	51264	801	8	64000	8*BIP-1	B2
STM1-MUX	153792	801	24	192000	24*BIP-1	B2
STM4-MUX	615168	801	96	768000	96*BIP-1	B2
STM16-MUX	2460672	801	384	3072000	384*BIP-1	B2
STM64-MUX	9842688	801	1536	12288000	1536*BIP-1	B2
STM0-REG	51840	6480	1	8000	BIP-8	B1
STM1-REG	155520	19440	1	8000	BIP-8	B1
STM4-REG	622080	19440	4	32000	4*BIP-8	B1
STM16-REG	2488320	19440	16	128000	16*BIP-8	B1
STM64-REG						

3.0 Anomalies

Anomalies are basic objects used for computing performance events as described in the chapter 6. Generally speaking, an anomaly will occur at detection of a wrong EDC. For PDH paths, an error in the frame alignment word will also be considered as an anomaly.

Anomalies on a bi-directional path can be detected by monitoring a single direction. They will be anomalies at near end corresponding to the forward path - the monitored one - and anomalies at far end corresponding to the backward path. For instance an MS-REI will be considered as an anomaly of the backward SDH multiplexing section. The tables overleaf show the global picture.

Anomalies at Near End

System	PDH	SDH Low Path	SDH High Path	SDH Mux Section	SDH Reg Section
A1 A2	Errored FAW Errored EDC	Errored EDC	Errored EDC	Errored EDC	Errored EDC
Recommendation	G826	G826 & G828	G826 & G828	G829	G829

Anomalies at Far End

System	PDH	SDH Low Path	SDH High Path	SDH Mux Section	SDH Reg Section
A1		LP-REI	HP-REI	MS-REI	
Recommendation	NA	G826 & G828	G826 & G828	G829	NA

4.0 Defects

The second type of basic objects used in the computation of performance events are defects. Defects are alarms. Depending on the kind of system, a different set of alarms will be considered as defects, as shown in the table below. A distinction is made between defects in forward and backward directions.

Defects at Near End

System	PDH	SDH Low path	SDH High Path	SDH Mux Section	SDH Reg Section
D1	LOS	HP-SLM	AU-AIS	MS-AIS	LOS
D2	AIS	HP-LOM	AU-LOP		LOF
D3	LOF	TU-LOP	HP-TIM		RS-TIM
D4		LP-TIM	HP-UNEQ		
D5		LP-UNEQ			
D6		LP-VCAIS			
Recommendation	G826	G826 & G828	G826 & G828	G829	G829

Defects at Far End

System	PDH	SDH Low Path	SDH High Path	SDH Mux Section	SDH Reg Section
D1		LP-RDI	HP-RDI	MS-RDI	
Recommendation	NA	G826 & G828	G826 & G828	G829	NA

5.0 Events

There are five basic events described in ITU-T recommendations. Their definition is almost the same, but may differ slightly from one recommendation to another. All apply on unidirectional links. For bi-directional links, there are events on the forward direction, computed thanks to anomalies and defects associated to the forward direction. There are also events in the backward direction, computed thanks to anomalies and defects associated to the backward direction.

- EB, Errored Block (G826, G828, G829): Block with one or several errored bits.
- ES, Errored Second (G821, G826, G828, G829): In G821 the definition is a period of one second including one or several errored bits, or during which an LOS or an AIS is detected. In G826, G828, G829 the definition is extended to a period of one second including one or several errored blocks, or at least one defect.

- SES, Severely Errored Second (G821, G826, G828, G829): In G821, it is a period of one second with a bit error ratio equal to or higher than 1E-3, or during which an LOS or an AIS is detected. In G826 and G828, it is a period of one second with a number of errored blocks equal to or higher than 30% of the total number of blocks in a second, or at least one defect. In G829, it is a period of one second with a number of errored blocks equal to or higher than X% of the total number of blocks in a second, or at least one defect. X depends on the bit rate as given below:

	STM-0	STM-1	STM-4	STM-16	STM-64
Multiplexing Section	15 %	15 %	25 %	30 %	30 %
Regenerator Section	10 %	30 %	30 %	30 %	ND

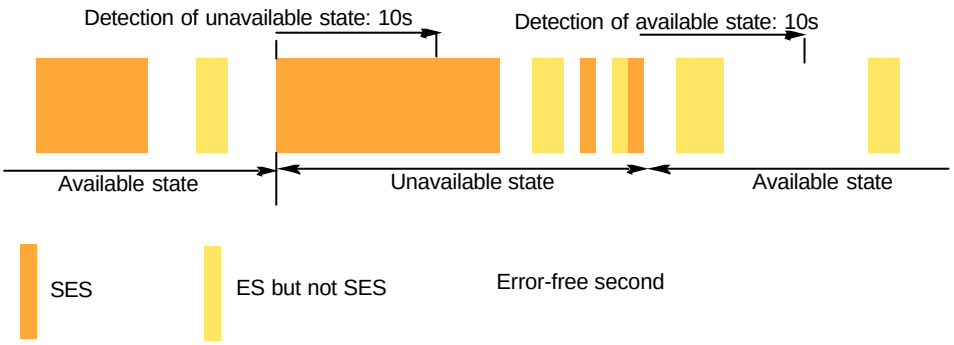
- BBE, Background Block Error (G826, G828, G829): It is an errored block not occuring as a severely errored second.
- SEP, Severely Errored Period (G828): It is a set of 3 to 9 consecutive severely errored seconds, ending with a non SES second. The use of this event is optional.

6.0 Availability

All recommendations give the same definition of unavailable and available time:

For an unidirectional link, an unavailable period starts with the occurrence of the first SES of 10 consecutive SES. An available period starts with the occurrence of the first non SES of 10 consecutive non SES seconds.

A bi-directional link is considered as unavailable. The following diagram is given in all recommendations:



7.0 Availability Parameters

ITU-T G827 and G827.1 define two availability parameters:

- AR, Availability Ratio
  The availability ratio is defined as the proportion of time that a path element is in the available state during an observation period.
  The Unavailability ratio UR is also used: AR+UR=1
- MO, Mean time between digital path Outage
  The mean time between digital path outage is the average duration of any continuous interval during which the path element is available. The reciprocal of MO is defined as the Outage Intensity OI.

8.0 Availability Objectives

ITU-T G827 is intended to define availability objective for Path Elements, whereas ITU-T G827.1 is intended to define availability for End to End Paths.

For Path Elements, objectives are defined as worst case values and mean values. But mean values are mainly intended to planning. Objectives depend on the kind of path element and on the length of the path element and on the bit rate.

In the last edition of G827, only the primary rate is defined, and for lengths shorter than 2500km.

Worst Case Unavailability Ratio

UR for E1/DS1	0-500km	500-1000km	1000-1500km	1500-2000km	2000-2500km
National Path Element	99E-4	146E-4	193E-4	240E-4	287E-4
International Path Core Element	75E-4	110E-4	145E-4	180E-4	215E-4
Inter Country Path Core Element	99E-4	146E-4	193E-4	240E-4	287E-4

Worst Case Outage Intensity

OI for E1/DS1	0-500km	500-1000km	1000-1500km	1500-2000km	2000-2500km
National Path Element	501	559	617	675	733
International Path Core Element	249	276	303	330	357
Inter Country Path Core Element	150	170	190	210	230

For End to End paths, objectives are defined for the Hypothetical Reference Path of 27.500 km, and are scaled down to real paths using allocation methods (see paragraph 13).

High priority, Standard Priority, Pre-emptible Priority levels are defined, but the objectives for AR and MO. All objectives apply to observation periods of 365 consecutive days.

9.0 Performance Parameters

Four parameters are used when assessing path performance. It is important to note that these parameters are not standardized for multiplexing and regenerator sections as no recommended limits or objectives exist for these sections:

- ESR, Errored Second Ratio (G821, G826, G828): It is the ratio of the number of errored seconds over the number of available seconds in a given period of time.
- SESR, Severely Errored Second Ratio (G821, G826, G828): It is the ratio of the number of severely errored seconds over the number of available seconds in a given period of time.
- BBER, Background Block Error Ratio (G826, G828): It is the ratio of the number of BBEs over the total number of blocks during the available seconds in a given period of time.
- SEPI, Severely Errored Period Intensity (G828): It is the ratio of the number of SEPs over the number of available seconds in a given period of time. The use of this parameter remains optional.

10.0 Performance Objectives

The parameter defined in paragraph 9 are used for setting performance objectives that have to be reached by an unidirectional path. In the case of bi-directional path, both objectives in the forward and in the backward direction have to be reached.

ITU-T defines the performance objectives of a hypothetical reference path of 27.500 km length (PO).

Path	Bit Rate Kbit/s	Block/s	ESR	SESR	BBER	SEPI	Recom.
DS1	1544	333	0,04	0,002	20^{-4}		G826
E1	2048	1000	0,04	0,002	20^{-4}		G826
DS2	6312	2000	0,05	0,002	20^{-4}		G826
E2	8448		0,05	0,002	20^{-4}		G826
E3	34369		0,075	0,002	20^{-4}		G826
DS3	44736	9398	0,075	0,002	20^{-4}		G826
E4	139264		0,16	0,002	20^{-4}		G826
VC11	1644	2000	0,01	0,002	50^{-5}	20^{-4}	G828
VC12	2240	2000	0,01	0,002	50^{-5}	20^{-4}	G828
VC2	6848	2000	0,01	0,002	50^{-5}	20^{-4}	G828
VC3	48960	8000	0,02	0,002	50^{-5}	20^{-4}	G828
VC4	150336	8000	0,04	0,002	10^{-4}	20^{-4}	G828
VC4-4C	601344	8000	NS	0,002	10^{-4}	20^{-4}	G828
VC4-16C	2405376	8000	NS	0,002	10^{-4}	20^{-4}	G828
VC4-64C	9621504	8000	NS	0,002	10^{-4}	20^{-4}	G828

For a real path, the conformance with the objective given above has to be scaled, and it becomes in practice equal to: Allocation* objective* test duration.

For testing the conformance of a given link, the recommended test duration is one month.

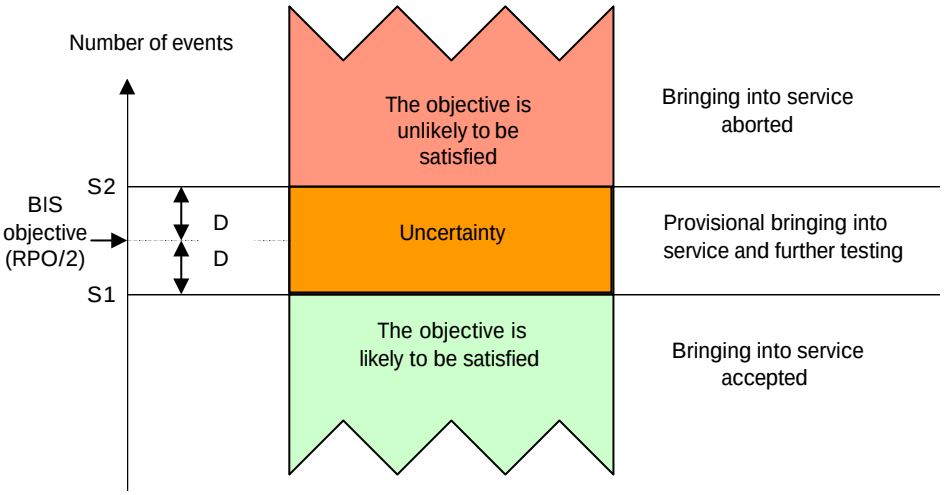
11.0 Performance Limits for Maintenance

In many cases, it is difficult to test a link during a one-month period. Therefore, shorter measurement periods are defined together with limits, which may be seen as short-term objectives. This is the case in three situations outlined in ITU-T recommendations.

11.1 Bringing into Service

Two thresholds are defined for each performance parameter. As shown in the figure overleaf, beyond S2 bringing into service will be aborted; below S1 bringing into service will be accepted. In between, provisional bringing into service and further testing in accordance with the procedure (see paragraph 14) may be pronounced.

S1 and S2 are derived from a BIS objective (BISPO) which is half of the RPO. RPO itself is equal to PO/2. The different ITU-T recommendations give tables of S1 and S2 for three different measurement durations used in the procedure: 2 hours, 24 hours and 7 days.



11.2 Keeping the Network Operational

Limits are defined for short-term measurements of 15 minutes and 24 hours. They relate to the Reference Performance Objectives (RPO). Three levels of performance are defined:

	Transmission Systems	Paths
Unacceptable Performance Level - UPL	> 10 * RPO	> 10 * RPO
Degraded Performance Level - DPL	>0,5 * RPO	> 0,75 * RPO
Acceptable Performance Level - APL	> 0,5 * RPO	> 0,75 * RPO

All these figures are identical in M2100, M2101.1 and M2101.

DPL should be evaluated over a 24-hour period, UPL over 15mm.

For UPL, 15mn thresholds are given in recommendations M2100 and M2101.

The concept of reset threshold corresponds to the generation of a report when the number of ES/SES/BBE returns to the reset threshold after exceeding it. These thresholds depend on the allocation (see paragraph 13). No thresholds are defined for concatenation VC4 and STM16, STM64.

Link/Path /Section	Allocation	ES Thres	BBE Thres	SES Thres	ES Reset	BBE Reset	SES Reset
PDH	3-4%	120	ND	15	4	ND	0
	4.5-7%	120	ND	15	5	ND	0
	7.5-10%	120	ND	15	6	ND	0
	10.5-11%	150	ND	15	7	ND	0
	11.5-13%	150	ND	15	7	ND	0
	13.5-15.5%	150	ND	15	8	ND	0
	16-18.5%	150	ND	15	9	ND	0
	19-20%	180	ND	15	10	ND	0
	20.5-21.5%	180	ND	15	11	ND	0
	22-24.5%	180	ND	15	12	ND	0
	25-27%	180	ND	15	13	6	0
	27.5-30%	180	ND	15	1	12	0
	30.5-33%	180	ND	10	2	25	0
	33.5-36%	180	200	15	1	50	0
	36.5-40%	80	300	10	3	25	0
	0.2-34%	120	700	15	1	50	0
VC-1, VC-2	35-63%	100	1100	10	4	200	0
	0.2-34%	150	700	15	1	400	0
VC-3	35-63%	120	1100	6	2	600	0
	0.2-34%	180	5000	10	2	1100	0
VC-4	35-63%	34	9000	6	4	5000	0
	0.2-34%	57	16000	10	ND	9000	
STM-0	35-63%	67	27000	6	ND	0	
	0.2-34%	114	128000	10	ND	0	
STM-1	35-63%	ND	220000	0	ND	0	
	0.2-34%	ND	15	1	ND	0	
STM-4	35-63%	ND	15	2	ND	0	
	120	ND	15	3	ND	0	
0.5-2.5%	120	ND	15	4	ND	0	

11.3 System Restoration

For a PDH transmission system or a multiplex section of an old SDH system (<March 2000): The performance limit recommended at 0.125 * Reference Performance Objective* Allocation* Duration.

For PDH and SDH paths:
The performance limit is recommended at 0.5 * Reference Performance Objective* Allocation*Duration.

12.0 Allocations

Performance objectives and performance limits are given for a hypothetical reference path. For a practical path, rules are also given for scaling the performance objectives and limits from the 27.500 km, and taking into account the lengths and the kinds of the links: this is the allocation procedure.

Allocation consists of calculating a percentage which will apply to the performance objectives/limits of the hypothetical reference path for giving the performance objectives/ limits of the considered path.

The principle consists of adding a percentage for the two national portions, and a percentage for the international portion. Both percentages include a fixed value and some value proportional to the distance. They also depend on the kind of link (satellite, submarine, etc.). For performance objectives, there are slight differences between G826 and G828 but the principle remains the same.

The same principle applies to the calculation of the allocation for maintenance performance limits.

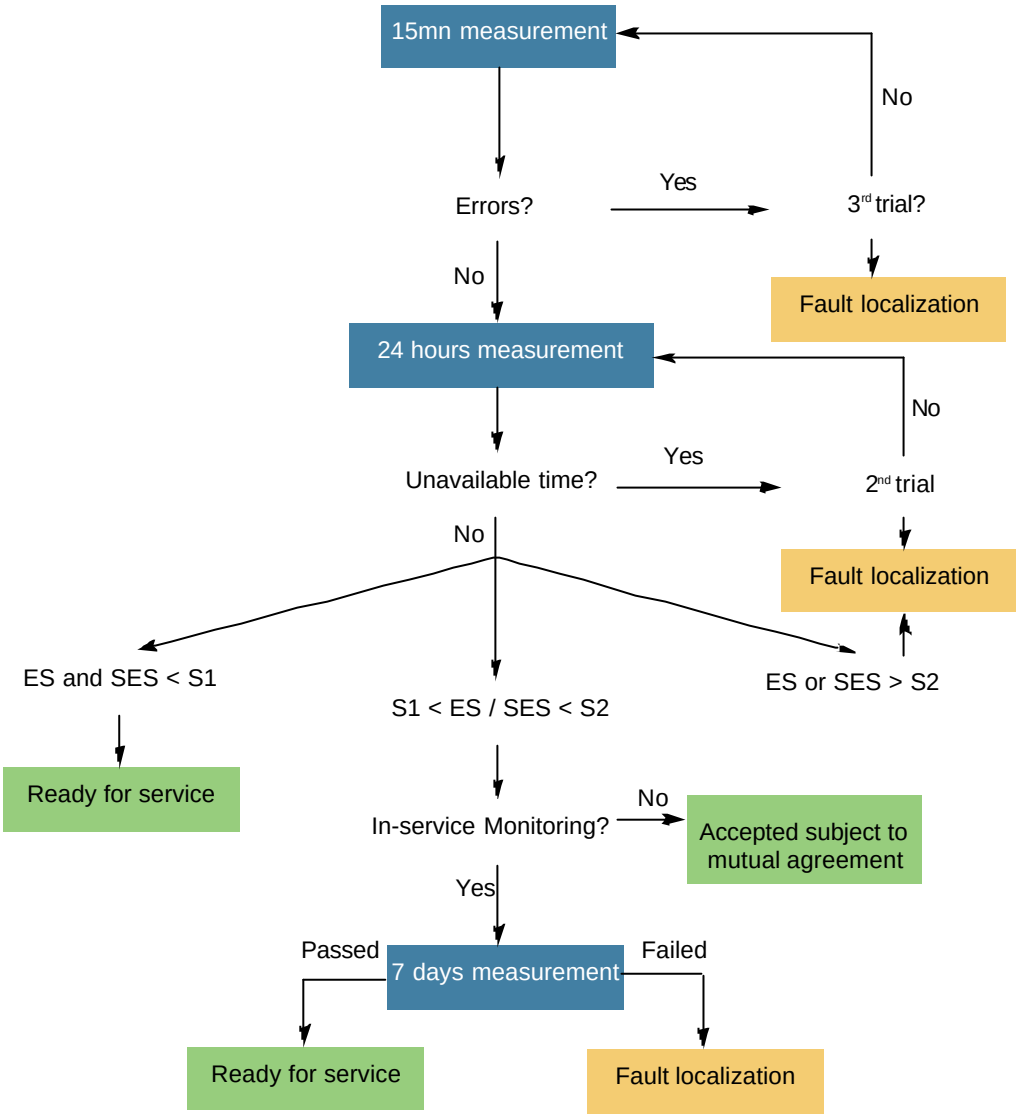
The point to point distance of the path has to be weighted by a routing factor of 1.5 for distances less than 1000 km and by a routing factor of 1.25 for distances in excess of 1000km(M2100, M2101.1) or 1200km (M2101). The routing factor is used when the real length is not known. For the determination of the maintenance performance limits (BIS, DPL) associated with the international part of a path, the calculation consists of adding the percentages as described in the table below:

		M2100 D	M2101.1 %	M2101 %
IPCE				
Terminating Transit National Network	0-100km	2	2	1.2
	100-200km	2	2	1.4
	200-300km	2	2	1.6
	300-400km	2	2	1.8
	400-500km	2	2	2
	500-1000km	3	3	3
	1000-2500km	4	4	4
	2500-5000km	6	6	6
	5000-7500km	8	8	8
	> 7500km	10	10	10
ICPCE				
Non Optical Undersea Cable	0-500km	2		
	500-1000km	3		
	1000-2500km	4		
	2500-5000km	6		
	> 5000km	8		
Optical Undersea Cable	0-500km	1	1	1
	> 500km	2.5	2.5	2.5
Satellite				
Normal Operation			ND	35
Wideband Cable Restoration Mode			ND	35
Terrestrial	0-300km		0.3	0.3

13.0 Procedures

13.1 Bringing into Service

M2110 defines the following procedure for bringing a path into service: S1 and S2 are the bringing into service limits as described above.



13.2 Fault Detection and Localization

Fault detection is a continuous process taking into account performance primitives (anomalies and defects), performance level information (unacceptable, degraded, normal), performance information (time stamped ES, SES, BBE), and supplementary information (constitution of a path, APS switches...).

This process is designed to report nine thresholds reached by the management center. These functions may be performed inside or outside a network element.

Threshold Report	Condition	Program Range	Default Value
TR1-ES	15mn threshold reached or exceeded	0-900	See paragraph 12.2
RTR1-ES	Less ES than 15mn ES reset threshold, after TR1-ES	0-900*	See paragraph 12.2
TR1-BBE	15mn BBE threshold reached or exceeded	$0\text{-}2^{16}\text{-}1/2^{24}\text{-}1$	See paragraph 12.2
RTR1-BBE	Less BBE than 15mn BBE reset threshold, after TR1-BBE	$0\text{-}2^{16}\text{-}1/2^{24}\text{-}1$	See paragraph 12.2
TR1-SES	15mn SES threshold reached or exceeded	0-900	See paragraph 12.2
RTR1-SES	Less SES than 15mn SES reset threshold, after TR1-ES	0-900	See paragraph 12.2
TR2-ES	24 hours ES threshold reached or exceeded	1-86400	
TR2-BBE	24 hours BBE threshold reached or exceeded	$0\text{-}2^{16}\text{-}1/2^{24}\text{-}1$	
TR2-SES	24 Hours SES threshold reached or exceeded	1-86400	

The localization procedure for PDH transmission systems and SDH multiplex sections consists of giving information on all paths carried by the section and in searching for the faulty Maintenance sub-entity. No means are defined in M2120.

Localizations procedures on PDH and SDH paths differ when In Service Monitoring is available and when Out Of Service means are used:

In an ISM environment, the path control station will be informed by the Maintenance Entity of the faulty multiplex section. When ISM is not available the procedure consists of:

- Determining path routing
- Sectionalizing the path, and performing simultaneous measurements using test instruments placed at protected monitoring points
- Ensuring there are no blind spots
- Coordinating measurement (synchronous start-stop)
- Centralizing results and using performance measurements to localize the faulty section

13.3 Restoration

When a path is returned into service, it should be monitored continuously for at least 7 days (M2120).

14.0 Measurements with Trans'Expert

Not only does the Trans'Expert compute the relevant availability and performance parameters in real time, but Trans'Expert also integrates all the calculations of limits and objectives required to describe the link, in compliance with ITU recommendations. Thus Trans'Expert is the ideal tool for performing Objective conformance measurement, Bringing Into Service measurement, Maintenance measurement and Restoration measurement.

14.1 How to Configure a Measurement

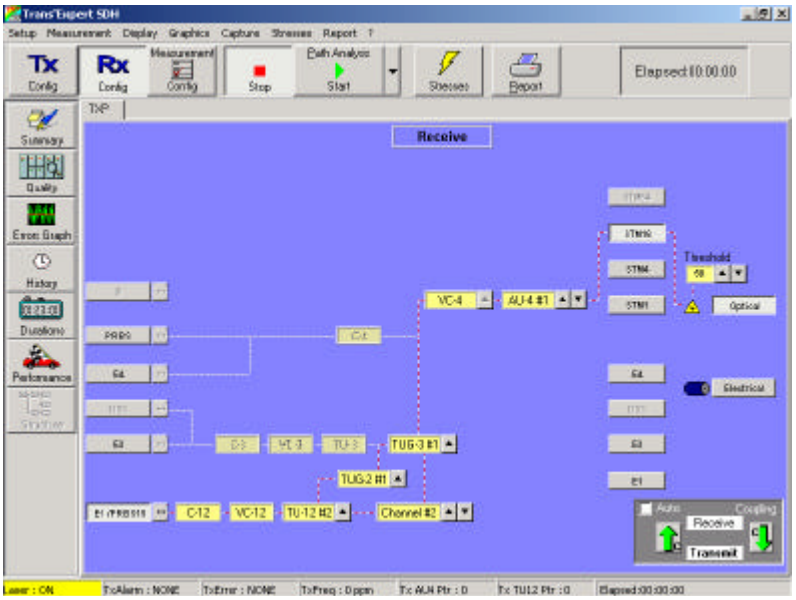
Select the Access You Want to Measure

- Open the Rx window.
- Click on the right hand button corresponding to the desired bit rate.

Select the Path You Want to Measure

In the Rx window:

- Click on the left hand button corresponding to the desired multiplexing structure.
- Define the VC4 number, using the arrows.
- Define the TUG number, using the arrows.



Receiver configuration screen.

Select the Duration of the Measurement

Open the Measurement Config window.

- In the area Start, select immediate or deferred measurement.
- In the area Stop, select Defined and 15mn, 24 hours, 7 days, 30 days bearing in mind the following table:

	15mn	24 Hours	7 Days	30 Days
Performance Objective Assesment				•
Bringing Into Service	•	•	•	
Maintenance	•	•		
Restoration			•	

Select the Kind of Measurement

In the area Performance, select the corresponding measurement: Objective, Bringing into Service, Maintenance, Restoration, Free Test. Trans'Expert will automatically select the relevant standard and will display it.

Select the relevant standard, if applicable.

- M2101.1, G826 for systems designed before March 2000.
- M2101, G828/G829 for systems designed after March 2000.

Define Your Thresholds

In the SetUp window, in the performance area:

- Click on the Multiplexing section button, and complete the window.
- Click on the High Path button, and complete the window.
- Click on the Low path button, and complete the window.

In these cases, a dedicated window will enable you to automatically compute the S1 and S2 thresholds, taking into account the bit rate of the link, the kind of measurement and the structure of the link.

You must specify the set of network elements your path is built of, and specify their length. Trans'Expert automatically computes the corresponding allocation and derives S1 and S2 or the RPO. Once defined, you may save/recall the path configuration.

Or, in the case of a free test you may enter your own thresholds in the table.

Optionally Define a Transmitted Signal

Open the Tx window.

- Click on the right hand button corresponding to the bit rate.
- Click on the left hand button corresponding to the multiplexing structure.
- Adjust the path numbers.

14.2 Visualize the Current Situation during the Measurement

Launch the Measurement

- Use the Start button and select "Path Analysis".

Access the Performance Parameters

- Press the Performance button.

The performance results are displayed on one or two windows, depending on the number of layers under test. The first window displays parameters associated with the Multiplexing Section and the High Path; the second window displays parameters associated with the Low PAth and the PDH tributary.

Both directions are simultaneously monitored when feasible.

Each bar graph shows the S1, S2 thresholds or the objective, as represented in the figure in paragraph 12.2.

In real time, on the occurence of performance events, a line will appear on the bar graphs at the height corresponding to the number of events. When thresholds are exceeded, the status of the path changes to acceptable, degraded or unacceptable.

Two visualization modes are available:

- Indicating the current situation with respect to the objectives/thresholds calculated at the end of the measurement
- Indicating the current situation with respect to the objectives/thresholds calculated at the current time

Easy to interpret graphical presentation for performance analysis result.

14.3 Create a Measurement Report

Configure the Report

Press the Report button. A configuration window appears. Select either complete report or custom report. In this last case, select at least Configuration and Performance. In the information part of the configuration window, enter free text. Then close the window by pressing the OK button.

Preview the Report

From the Report section of the main menu, select Preview. Then use the usual tools for displaying the report as you wish.

Print the Report

From the Report section of the main menu, select Print.

Save the Report

From the Report section of the main menu, select Save. Enter a file name. The file will be saved in the directory “Report”. By using the command Open in the Report section of the main menu, you can reload a report file for deferred preview or printing.

Convert the Report into PDF File

From the Report section of the main menu, select “Export to PDF”. This menu item only appears if Adobe Acrobat PDF Writer has been installed on the Trans’Expert. Then Acrobat is launched. After opening of the main window, just select”Save As” from the File section of the main menu.

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